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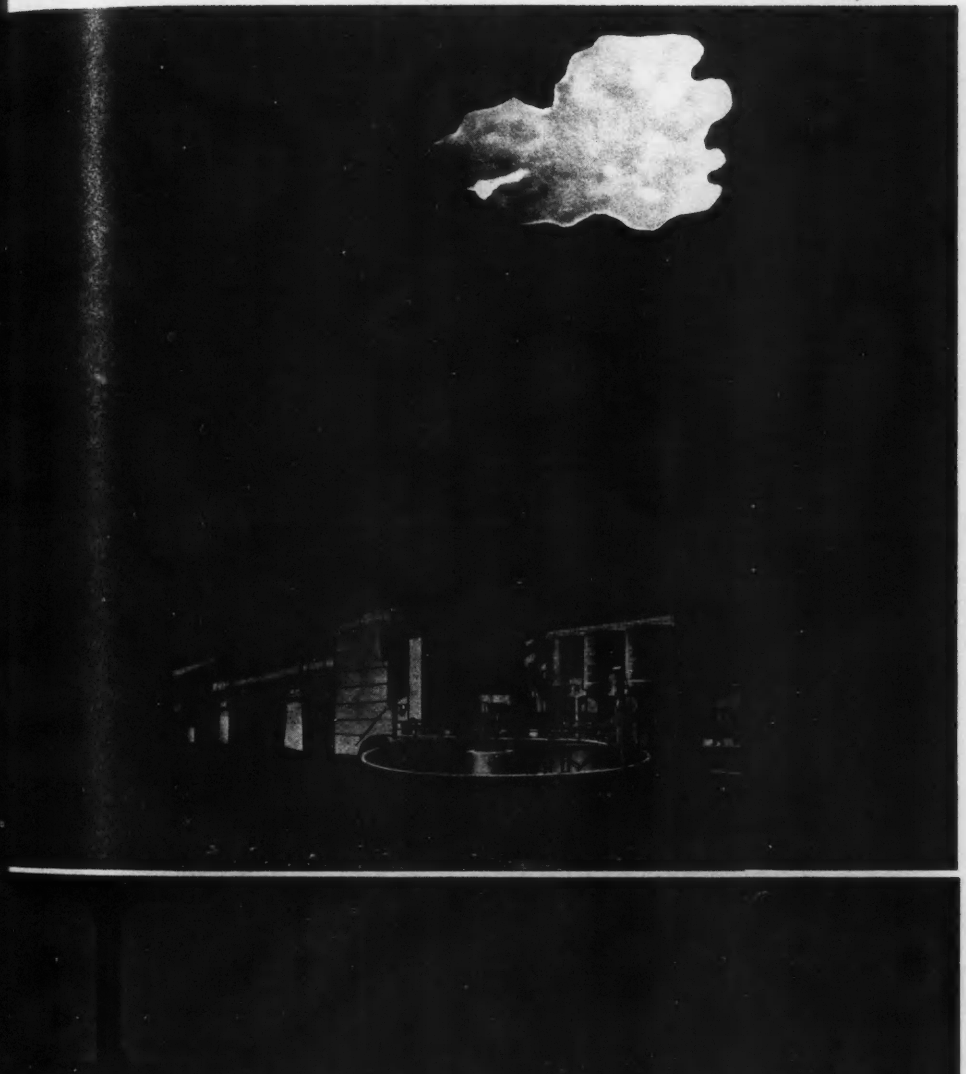

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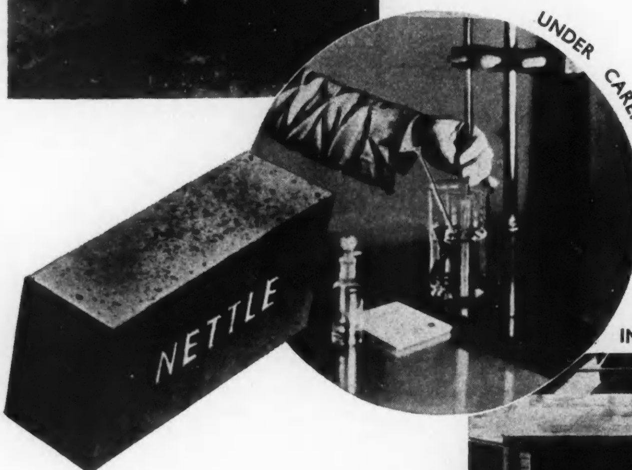

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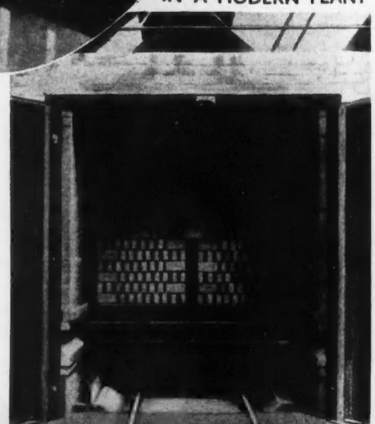

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Slurry Agitation by Pressure Air.

In our issue for August, 1939, we gave an abstract of an article from *Pit and Quarry* for July, 1939, describing a pressure-air equipment initiated by the Manitowoc Engineering Co. (U.S.A.) with special reference to the agitation of cement slurries. The article stated that under some conditions the lime content of the slurry, at some stage of the manufacturing process and with raw materials of varying analysis, might vary by as much as 15 per cent., but that this variation would be much lower with raw materials that were initially more consistent. This considerable variation may have resulted from the use of a clay slurry prepared in some form of washmill, having a moisture content that continually varied between 60 per cent. and possibly greater than 65 per cent., and being fed with crushed limestone of patchy composition in the mill for final grinding ; the varying moisture in the clay slurry would also call for a variable amount of make-up water. Several methods might have been adopted for measuring or adjusting the amount of feed of clay slurry, but the final mix as produced might still lack uniformity owing to the limestone being patchy or of variable composition.

In order to obtain a consistent lime content, etc., in the slurry, it is necessary for every part of the mix, and the quantities incorporated in the mix, to become of an increasingly uniform composition as it passes through the manufacturing process. The moisture content of the clay slurry and the amount of limestone fed to the mill should be reasonably constant ; if these two quantities are reasonably constant the variation in quality of the limestone alone has to be provided for.

Portland cement as manufactured to-day calls for precision of mix and manufacture through all the various stages, and the product finally obtained may be assumed to be an indication that this high standard has been attained. This article deals especially with the procedure necessary for obtaining a slurry that has been precisely controlled in all stages of its manufacture.

Clay Slurry.

Dealing first with clay slurry that has been obtained from a patchy raw material, the most, and possibly the only, satisfactory method would be to "wash" a considerable quantity of clay and store the slurry in bulk. Washing could be carried out in the usual way and storage effected in deep tanks of small diameter with a rather steep inverted cone bottom, and agitated with pressure air. Pressure air may at first sight appear costly for use in this way, but a consistent and uniform product will fully justify its use; moreover, the cost of power for producing pressure air is relatively small, as is shown later.

The pressure of the air, in lb. per square inch, used for agitation might be, say, 2½ to 3 times the hydrostatic pressure of the slurry at the bottom of the tank; if the tank had a depth of 50 ft., and the specific gravity of the slurry was, say, 1·25, the liquid pressure would be $0{\cdot}43 \times 50 \times 1{\cdot}25 =$ say, 27 lb. per square inch, and the pressure of the air for agitation, say, 70 to 80 lb. per square inch. The liquid pressure will be subject to small variations owing to the varying moisture content of the slurry, and more so owing to the varying depth of slurry in the tank. There would be no necessity for agitation to be continuous, as one good "blow" every 10, 15, or 20 minutes would probably be sufficient; the time between the blows would actually depend upon the settlement characteristic of the slurry. The volume of "free" air per blow might be, say, 7½ per cent. of the volume of the slurry to be "blown," and a receiver having a working capacity of this amount should be provided. The compressor need be only small if a single tank is its exclusive duty, as the receiver will need pumping up only once in every 10, 15, or 20 minutes as indicated. The power required by the compressor can be obtained from *Fig*. 4.

The use of pressure air under these conditions and in a tank of considerable size and depth will ensure a thorough mix of the bulk material as well as a uniform moisture content. The moisture may not be quite as desired but it will be consistent, and any error in moisture can be corrected at the washmill and an adjustment made in the amount of make-up water at the grinding mill.

If the tank were 12 ft. diameter and the mean depth of slurry 50 ft., the volume of the slurry in the tank would be, say, 5,600 cu. ft., and 7½ per cent. of this figure would call for, say, 420 cu. ft. of free air per blow. A summary of the basic data involved is as follows:

Range of receiver pressure: 80 and 27 lb. per sq. in. gauge.
=95 and 42 lb. per sq. in. absolute.

The difference in the volume of free air under the 80-lb. and the 27-lb. per square inch conditions respectively is

$$\frac{80 + 15}{27 + 15} = \frac{95}{42} = 2{\cdot}25, \text{ and } 2{\cdot}25 \times 420 = 940 \text{ cu. ft.}$$

The volume of the receiver required will thus be $940 \times \dfrac{15}{15 + 27} = 325$ cu. ft.

Suitable round-figure dimensions for the receiver are 6 ft. diameter × 11 ft. to

11 ft. 6 in. long. The volume of free air in the receiver under high and low pressure conditions will be

$$80 \text{ lb. per square inch gauge} = 325 \times \frac{80 + 15}{27 + 15} = 740 \text{ cu. ft.}$$

$$27 \text{ lb. per square inch gauge} = 325 \times \frac{27 + 15}{15} = 325 \text{ cu. ft.}$$

Quantity of free air per blow = 415 cu. ft.
or, in round figures, say 420 cu. ft.

If a blow were required every 15 minutes the capacity of the compressor required would be $\frac{420}{15}$ = say, 28 ; or, to provide a small reserve, say, 30 to 35 cu. ft. of free air per minute at a pressure of 80 lb. per square inch gauge. The power required by the compressor will be as obtained from *Fig.* 4 ; it appears to be about 11 B.H.P. per 100 cu. ft. of free air compressed.

The diameter of the discharge pipe adopted should result in a sustained or continuous blow rather than in a violent or explosive discharge ; it is possible that a discharge period of 12 to 15 seconds would result in the best mix, but this can be determined best during the starting-up and initial adjustment of the plant. The rate of discharge of air should result in intensive bubbling of the slurry. The pressure air may initially raise the surface level of the slurry by 10 in. or even 20 in. ; in the meantime the bubbles burst and the air pressure in the receiver falls. Two, three, or several blows may be required initially, but intermittent blows may be sufficient with a tank that is being constantly pumped into and drawn from.

Fig. 1 shows a single tank and a grouped arrangement of an equipment such as that indicated. The separate units would be located to suit site conditions, but the line of the air-discharge pipe, passing over the top edge of the tank and extending to or near the bottom, as indicated, should be especially noted as it is imperative for this to be as shown. In the diagram, the compressor (A) delivers pressure air to the receiver (B) until the pre-determined pressure, for which the spring-controlled pilot valve (C) is set, is obtained. The pilot valve (C) then opens and allows pressure air to pass under and raise the trunk-piston discharge valve (D) ; this allows pressure air to flow from the receiver (B) through the pipe (BD), the valve (D), and the pipe (DE) to the tank (E), until the receiver pressure has fallen to, or near, the hydrostatic pressure of the liquid at the base of the tank. In the meantime the pilot valve (C) closes under the action of its spring, and the trunk piston discharge valve (D) also gradually closes owing to the pressure air that opened it having been allowed to exhaust. The time rate at which the cylinder underneath this valve exhausts is usually controlled by an adjustable leakage screw ; in any case the increasing pressure of the air over the top of the valve will soon ensure its effective closing, and pressure air will again build up in the receiver.

This brief description indicates the simplicity of the arrangement as well as its automatic operation and the probable efficiency of the equipment so far as

the mixing of the slurry is concerned. The regularity of the clay slurry feed, the settlement characteristic of the clay slurry, and the average or working volume of slurry in the tank will quickly determine the best operating conditions. If the plant is proportioned correctly and operated regularly, the slurry as used should be found reasonably consistent ; needless to say the consistency of the slurry mix will be a factor of the size or the volume of the slurry tank—the larger the tank the more consistent the mix, other things being equal or comparable.

Finished Slurry.

The equipment and procedure for dealing with the finished slurry would be of the same type, in principle, as that described for the clay slurry, but modified

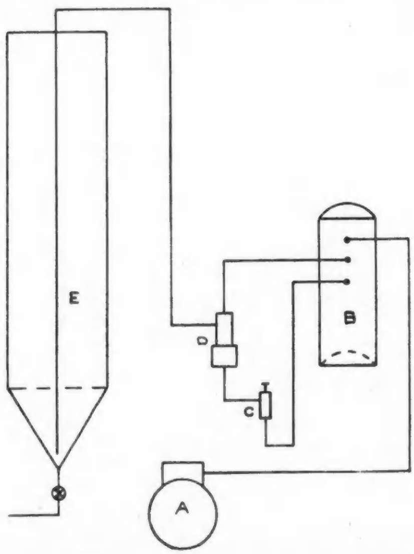


Fig. 1.—Single Tank with Compressed-air Agitation.

and elaborated to suit a wider range of duties and conditions. There are usually two classes of tank provided for processing the finished slurry, namely, one for the slurry being processed and the other for the slurry in storage. The former would be called the " doctor " tank(s) and the latter the " storage " tank(s), or more frequently—but incorrectly—" mixers."

The doctor tanks are usually of small diameter and relatively deep ; the depth may be four or five times the diameter. Two, three, or even four doctor tanks comprise a set, and each tank serves a definite purpose. Storage tanks are usually of large diameter and relatively shallow ; the depth might be, say, 0·2 to 0·25 times the diameter. The number of storage tanks would depend upon the capacity of the works, and the added capacity of all the tanks should be equal at least to four or five days' requirements of a works at full output.

The slurry is pumped as produced into one or other of the doctor tanks ; it is then thoroughly " blown " for blending, tested for carbonate (lime), and corrected if necessary (or a record made of the error). The slurry would then be run off into one or other of the storage tanks. While the blowing, etc., is proceeding the second doctor tank would be filled with slurry from the mill, and this would be treated in the same way as that of the first tank. Two tanks will thus be required for normal working, and a third tank would be necessary to provide against delay in any part of the process or if the mix were likely to prove too far from correct for passing into storage. Under these conditions it would be necessary to " wash " for the third, or possibly even a fourth, doctor tank and use the slurry as a corrective for the tank in error and run them—or a portion of them—into storage together. Several variations of this kind are possible if a number of doctor tanks is available, and additional tanks invariably prove useful owing to the increased amount of storage they represent. Good blows, as frequent as practicable, are necessary for the doctor tanks to ensure that blending is completely carried out. The samples for testing should also be taken during, or immediately after, the blowing procedure to ensure that a fair sample is obtained.

Agitation in the storage tanks should be continuous but not necessarily violent. No blending should be necessary at this stage, but the pressure and the quantity of air should definitely ensure against settlement of the larger particles. Mechanical stirrers have been in use for many years but their mixing value has been proved to be very small. Cases have occurred where the carbonate content of the slurry at or near the bottom of a storage tank 10 ft. to 12 ft. deep has been found to be $1\frac{1}{2}$ per cent. higher than that at or near the surface of the tank when full. This large difference should be considered prohibitive for a high-class product ; in fact, a difference of not more than 0·1 per cent. to 0·2 per cent. should be regarded as easily attainable when pressure air is used and the equipment correctly applied.

In a number of instances the mechanical stirrer equipment has been removed from large diameter shallow tanks and pressure air equipment substituted. This change can usually be made without difficulty and a large portion of the value of the original machinery retained. In making a change of this kind the motor-compressor has been mounted on the girder and the details arranged so that the tank as a whole can operate as a self-contained unit ; this, under some conditions, would be considered an advantage. The compressor usually adopted for this duty is of the medium-speed, air-cooled type and, with a suitable arrangement of piping, should ensure pressure air of relatively low temperature (the temperature rise of compression at 8 or 10 lb. per square inch is actually 70 deg. F. to 85 deg. F.). This low temperature is important, as it avoids or reduces the tendency of the slurry, which may be of varying depth in the tank, to build up, or dry, or burn on the inner surface of the discharge pipes and so prove troublesome. In any case, whatever precautions are taken, it is desirable also to have a plug fitted at the top of, or over, each discharge pipe so that if blocking occurs the plug alone will have to be removed in order to clear the pipe.

Fig. 2 indicates a group of doctor tanks wherein the pressure air may be taken to any one tank for blending or, alternatively, distributed between the whole group of tanks, to ensure against settlement, when they are used for storage. The compressor will need to be much larger, possibly considerably larger, than that used for clay slurry; the density of the slurry will be higher, actually it may be about 1·6 times the density of the clay slurry, and this in turn will call for a rather higher operating pressure. In this arrangement the pressure air is passed from the compressor (A) to the receiver (B), and through the spring-controlled pilot valve (C) to the pressure-controlled discharge valve (D) and the distribution box (E), but is controlled by hand-operated valves beyond this point. Only

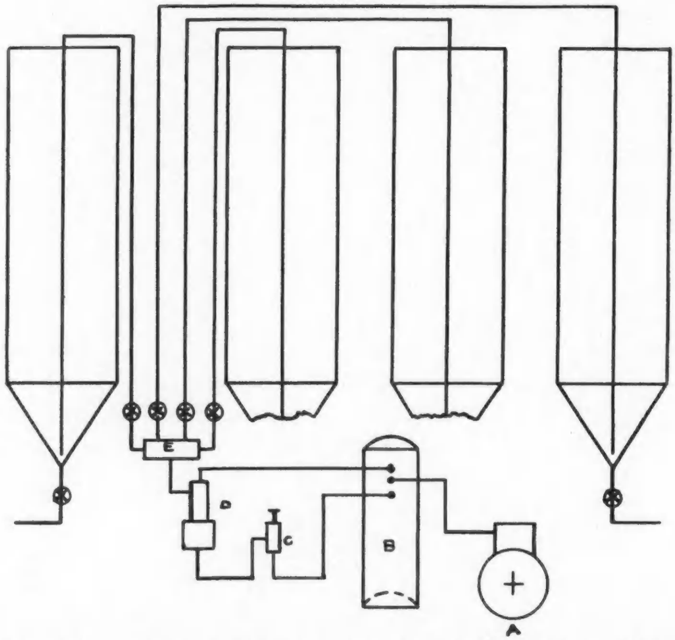


Fig. 2.—Group of Tanks with Hand-controlled Pressure-air Equipment.

one valve would be opened and one tank dealt with at a time for blending purposes, but any number of valves would be opened and any number of tanks dealt with in storage. The equipment is automatic for both duties except for opening or closing the valves for a change of duty.

If the tanks were of large capacity, or if the number was large, it might be desirable to have a second compressor, and to operate two under blending conditions in order to carry out blending in a shorter time; that is to say, only one compressor would be working under storage conditions but the second compressor would be put into service when blending was being carried out. Much, however,

would depend upon the number and size of the tanks as well as upon the size or the capacity of the compressor.

The group arrangement indicated in *Fig.* 3 is designed for storage exclusively, and is arranged to work automatically except under very abnormal conditions. The arrangement differs from that of *Fig.* 2, as a pressure-operated sequence valve has been substituted for the distribution box with hand-operated valves; the arrangement also provides for the isolation of one or even two tanks if they are out of service. A brief description of the method of operation is as follows. Units (A), (B), and (C) operate as before. After passing (C), a small quantity of pressure air enters into and through the pressure-operated sequence valve (D). Pressure air then enters and operates one or other of the discharge valves (E) as before. The pressure air, in passing through (D), causes part rotational

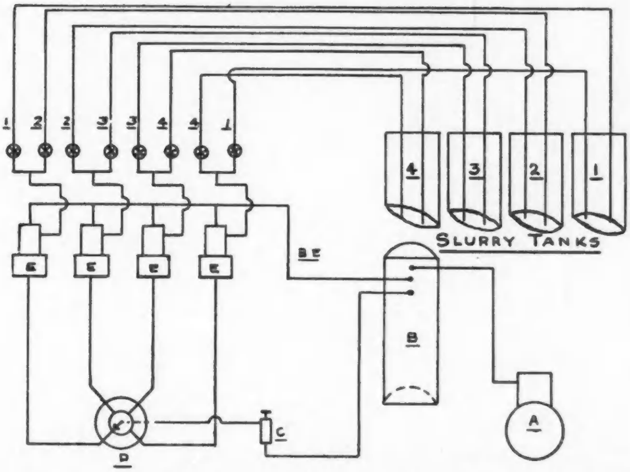


Fig. 3.—Group of Tanks with Automatically-controlled Pressure-air Equipment.

movement and directs the flow of pressure air to each of the discharge valves (E) in turn. The amount of angular movement of the sequence valve is arranged to suit the number of tanks to be served. Each branch pipe beyond the discharge valves is divided into two parts, and these pipes are led, one each, to two tanks instead of only one tank; this arrangement avoids all possible difficulties with the sequence valve in the event of one or the other of the tanks being out of service and its valve closed. If one valve of each pair were closed the arrangement could be worked as a simple storage system, the divided discharge being used only when one or other of the tanks was out of commission. The wide range of operating conditions made possible by this arrangement has much to commend it. The capacity of the compressor and the volume of the receiver would need to be suitable for the size and total number of tanks that the equipment serves.

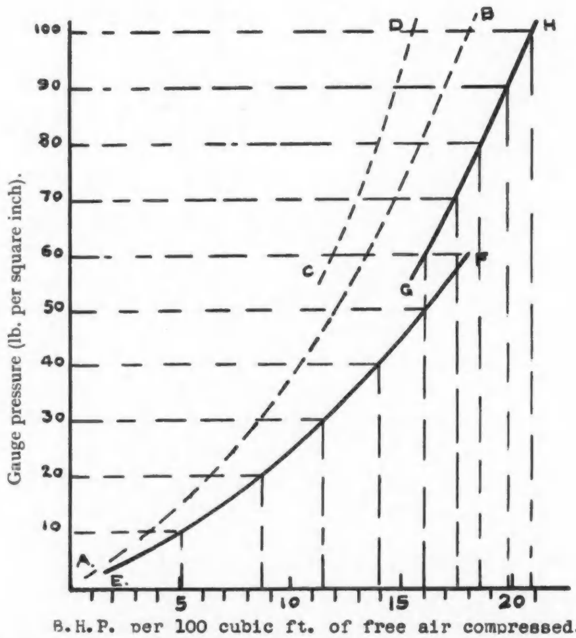
No diagram has been drawn for the large-diameter shallow storage tanks subjected to continuous agitation, but the following data may prove satisfactory for slurries of usual moisture and of average density.

Time period of girder rotation : Once in five or six minutes.

Diameter of air pipes : $\frac{3}{4}$ in. or 1 in. ; either size will require support to prevent bending.

Radial distance between adjacent pipes : 12 in. to 15 in.

Air quantity : 12 to 15 cu. ft. per pipe per minute ; the denser or the low moisture slurries will call for the larger quantity.



Curves AB and CD indicate the power required under adiabatic conditions assuming there were no losses of any kind in the compressing process. Curves EF and GH indicate the actual power that would be necessary assuming an overall compressing efficiency of 74 to 75 per cent.

Fig. 4.—Power Required for Compression.

Air pressure : 10 or 12 lb. per square inch for a slurry depth of 10 ft. to 12 ft. This pressure is a function of the slurry density, of the size and number of pipes, and of the absence of blockage within the pipes. If the slurry tends to settle quickly, drag chains may be necessary, to prevent settlement or building-up on the floor of the tank ; chains should be provided initially as a precautionary measure.

If the moisture in the slurry is low or the slurry is of considerable density, a liberal supply of air should be provided ; if the slurry moisture is high and the density low, less air may prove satisfactory. In arriving at the quantity of air, it should be remembered that a liberal quantity of air will probably mean an absence of trouble, whereas a limited quantity may encourage or result in trouble.

Having determined the proportions of the plant and the quantity of pressure air that will be required, the power required for compressing the air can be arrived at from *Fig.* 4. Referring to the figure, it may be stated as a general rule that single-stage compression will usually meet all conditions for pressures up to 50 lb. per square inch, but two-stage compression should be adopted for all pressures above 60 lb. per square inch.

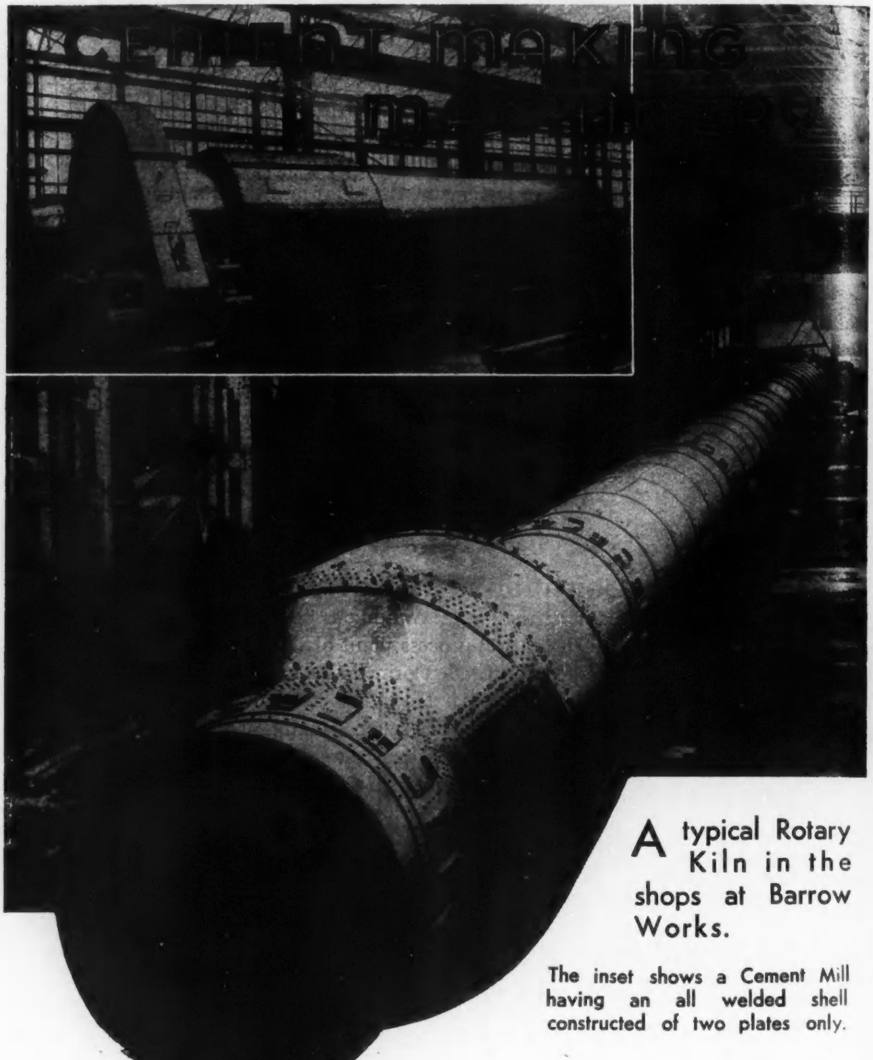
It may be stated with confidence that a more complete blending and mix of slurry will be obtainable with the use of pressure air than by any other method. It must, however, be added that the whole equipment should be designed for the quantity and the type of slurry to be dealt with and with due consideration of the settlement characteristics of the raw materials.

Large Continuous Disc Slurry Filters.

What are said to be among the largest continuous disc filters for 10 ft. by 150 ft. kilns have been installed at a wet-process plant of the Medusa Portland Cement Co. in Ohio. The filters were installed principally to conserve coal. Operating results can only be given in approximate figures since they are based on only a few months' operation of two units, but fuel consumption has dropped considerably. After the filters had been installed it was found desirable to alter the slurry consistency from 35 per cent. to 40 per cent. moisture to facilitate handling through pipelines and to prevent segregation in the filter tanks, but it has also increased the grindability of the raw materials and improved the uniformity of the slurry. Filter cake, as fed into the kilns, contains about 18 per cent. moisture, so that about 150 lb. of water per barrel of cement is removed by filtration.

The production of clinker also has been increased per kiln hour. The waste-heat boiler efficiency is much improved ; each kiln has a separate 761-h.p. waste-heat boiler, with economiser and induced draught fan, and all three exhaust through a common stack. Stack gases had a temperature of 1,100 to 1,200 deg. F. upon entrance into the boilers when unfiltered slurry was fed into the kilns. It is estimated that the temperatures are now several hundred degrees higher. The plant can be operated by the power generated from waste-heat boilers without auxiliary coal-fired boilers.

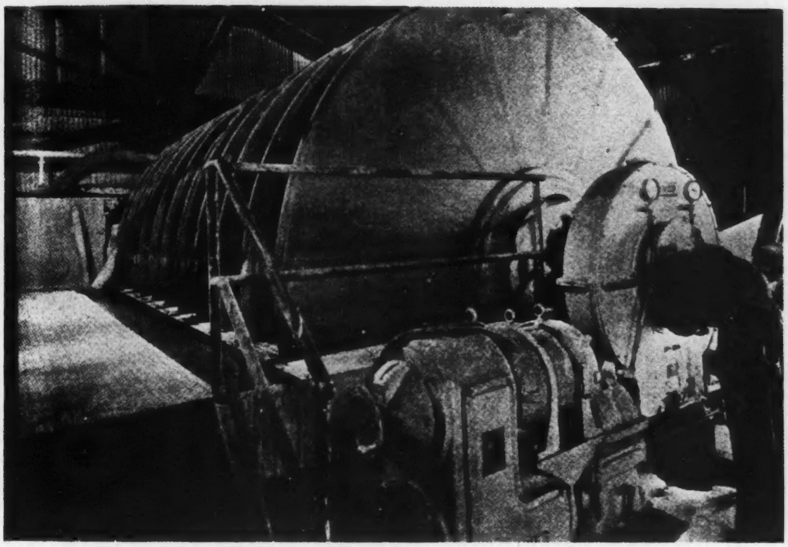
Each filter is installed just over the feed end of the kiln and its source of slurry is a 1,000-barrel storage tank of corrected slurry on the ground level below. Slurry is ground to 98 per cent. minus 100-mesh. After blending and correction, it is pumped into the correction tanks, from which a 4 in. slurry pump elevates the



slurry into ferris-wheel feeder tanks at the filters. Each filter has 11 discs, 12 ft. 6 in. in diameter, with 16 sectors. Overall, a filter tank measures 24 ft. $4\frac{7}{16}$ in. long and the filter has 2,398 sq. ft. of filtering surface. It has a direct-geared electric motor drive through a gear reducer connected to a $2\frac{1}{2}$-h.p. to $7\frac{1}{2}$-h.p. motor with four speed ratings.

An automatic valve controls the cycles of cake formation, washing, drying and discharging. Filter cake is discharged by gravity aided by a slight inflation of the filter cloth, automatically operated through the valve. Cake is removed by rubber-edged blades.

Each of the ferris-wheel slurry feeders has twelve buckets, and there is an adjustable pulp-level weir on each tank. Control is based on having the required

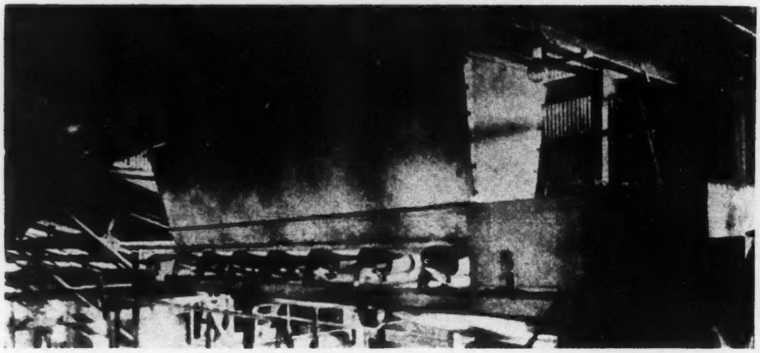


Slurry Filter with Discs 12 ft. 6 in. in Diameter.

amount of slurry always available to the filters. The kilns are driven at a speed of either one revolution in two minutes or one in four. When the kiln speed is changed the speed of the ferris-wheel feeder automatically changes proportionately through interconnected rheostats on the feeder and kiln drives. Slurry enters the filter troughs through a 4 in. pipe from the feeder tank, and the operator regulates the speed of the filter, as the kilns are speeded up, to maintain the level in the trough.

Moisture in the feed slurry was increased from 35 to 40 per cent. to help maintain a uniform mix, to improve pumping, and to get a more uniform distribution of slurry in the filter troughs to ensure a level throughout that is necessary to maintain a vacuum. Filtered water flows by gravity into a trap. A second

water trap removes the water ahead of the vacuum pump. Channels are provided inside the cast-iron filter shaft for the movement of filtrate, wash water, and blow-back air. Filter cake is discharged on to a horizontal 24 in. belt conveyor that carries it to a pug mill just over the kiln-feed chute, where it is mixed with dust reclaimed from the kiln and boiler housings just before discharge into the kilns. Until the filters were installed, dust so reclaimed from all the kilns was fed into one kiln, but now it is divided evenly between the kilns. Screw conveyors and elevators take the dust to 7-ton bins near the pug mills. Dust is drawn from the boilers and kiln housings once each shift, and is fed uniformly from the bin into the pug mill by a 6 in. enclosed-screw conveyor. The addition of the dust to



Feeding Filter Cake on to Belt Conveyor. It is then mixed with Kiln and Boiler Dust in Pug Mill to the right.

the filter cake partially dries the wet surfaces and helps to prevent sticking in the kiln-feed chute, which is of special heat-resistant steel covered with asbestos near the bottom end. It also helps to prevent mud rings and reduces the moisture in the cake, possibly by ½ per cent. It is necessary to have a pitch of about 45 deg. to the kiln-feed chute to prevent the filter cake from going back up into the boilers. Each kiln will have spiral lifters at the back end of the kiln to augur the filter cake into it as fast as the feed comes in, thus preventing the formation of mud rings. [We are indebted to our contemporary, "Rock Products," for the foregoing notes.]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